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ORIGINAL MEMOIRS.

HYPERTROPHIC STENOSIS OF THE PYLORUS IN INFANTS.*

BY ARTHUR LYMAN FISK, M.D.,

OF NEW YORK,

Surgeon to the Babies' Hospital, and to Trinity Hospital.

PYLORIC stenosis in infants has within the last twenty years, only, especially commanded the attention of the profession, although the earliest record of a case of this sort goes back to 1788, when Hezekiah Beardsley, of New Haven, Connecticut, gave the history of a child which had "puking and regurgitation of milk," from birth until the time of death at five. Following this report there is an interval of fifty-three years before the second case was recorded by Williamson, in 1841, and in the following year Dawaski reported the third case. Both of these infants died when five weeks old. After this there was another long interval of forty-six years, when Hirschprung, of Copenhagen, in 1888 again brought stenosis of the pylorus in infants to the notice of the medical profession. Since which time an active interest has obtained, so that, at the present time, there is a record of 121 cases.

* Read before the New York Surgical Society, March 28, 1906.

Ibrahim states that of 113 cases, 50 occurred in Germany, and 49 in England; 71 of the cases were operated upon, and 50 died without surgical interference.

Stern¹ was the first to attempt surgical treatment, in 1897, in a correctly-diagnosed case. Scudder credits the first operative case to Meltzer in 1898, and the first successful operative case to Löbker, on July 25, 1898.

Symptoms.—In about every case it has been noted that the infant was a “fine baby.” Many of the cases are in breast-fed infants.

The first symptoms may come on a few hours after birth or may not appear for a month or more. Usually they appear in the second or third week. Until vomiting commences there may be no evidence of anything wrong. There may be flatulence and constipation. Vomiting is the prominent and characteristic sign. The intervals between the attacks may be fairly long. In well-marked cases several feedings may be kept down and then apparently the whole lot is brought up at once. Vomiting gradually becomes more and more frequent, and may occur on the administration of the smallest quantities of food. The act of vomiting is *forcible* (projectile); it causes some pain, and the infant is most comfortable when the stomach is empty. The character of the vomiting depends upon the diet. Change of food causes a cessation in the vomiting, often, for a short time, but it soon recurs. No bile is present. Constipation may be present throughout and may be a marked feature. It is not invariably present, being dependent upon the amount of stenosis. Sometimes there is actual diarrhœa. This results from irritation from decomposed or unusual foods which pass through the pylorus. The tongue is clean and the breath sweet in typical cases. Upon inspection of the abdomen usually there is distinct evidence of gastric dilatation and visible peristalsis may be present. In a marked case a wave of peristalsis may be seen passing from left to right, stopping

¹ Deut. Med. Woch. 1898, p. 601.

at the pylorus momentarily and then passing on downward into the duodenum. Tapping the epigastrium or applying cold may start this wave. The pylorus can usually be felt on careful palpation.

The average position of the pylorus can be marked on the body by the intersection of two lines; one drawn horizontally half way between the top of the sternum and the pubic crest, the other drawn vertically a little way (one-half inch) to the right of the middle line (Cunningham). Cautley says it is about one-half inch to the right and three-quarters of an inch above the umbilicus. It is deeply seated and feels about the size of a filbert. Cautley states that he has been able to feel it in the last five of his cases.

Wachenheim says that "Palpation of the pylorus is of an uncertain quantity and is frequently rendered difficult or impossible by the almost continuous crying of the infants, with resultant tension of the abdominal walls."

The body weight decreases rapidly and emaciation is often extreme. The ratio of sex is: males, 2.5 to females 1.

The following case was admitted to the Babies' Hospital in February, 1906, the second case only in the history of the hospital:

E. M., born December 24, 1905. U. S. Female, white. Normal birth. Weight $8\frac{1}{2}$ pounds. Breast fed. At two weeks given a bottle at night, next day vomited at breast. Given three bottles in all, then stopped. Gained seven ounces in the following week. Vomiting ceased for one week, then commenced again; after each nursing explosive vomiting. Change of food and careful regulation of no avail. Entered Babies' Hospital February 3, 1906. Child much prostrated, eyes sunken, color grayish; appears to be dying. Heart and lungs normal. Abdomen depressed, little fat, no mass, temperature 99.2° , weight 7 lbs. $9\frac{1}{2}$ oz. Given barley water. During February 3, child retained nothing by rectum or stomach.

February 4, retained a little 1-6-90. Vomited three times during the day, and three times at night. Stool meconium.

February 5, retains some breast milk. Temperature, 104° . Rectal irrigation expelled, also lavage.

February 6, vomited twice; 50 c.c. salt solution subcutaneously. Meconium stool. Temperature, 101.4° .

February 7, doing better. Vomited once in twenty-four hours. Temperature, 99° . Fecal stool.

February 8, vomited four times.

February 9, vomiting; losing ground.

February 10, condition same. Weight 7 pounds, $8\frac{1}{2}$ ounces. Temperature, 101.2° .

February 11, regurgitating and vomiting. Cries considerably. Pyloric tumor not felt. No peristaltic wave.

February 12, given breast milk; still vomiting. Weight, 7 pounds, $9\frac{1}{2}$ ounces.

February 14 and 15, vomiting persists.

February 17, peristaltic wave noticed. Vomiting. Given condensed milk.

February 18, condensed milk retained.

February 20, vomiting considerably. Operation advised.

February 21, child exceedingly prostrated, does not respond to stimulation.

February 22, decidedly weaker. Operation not thought advisable because of the child's weak condition and failure to respond to stimulation.

February 23 and 24, progressively weaker, persistent vomiting.

February 25, died.

Autopsy.—Stomach capacity two ounces. Through the walls the pylorus feels very thick and cartilaginous; on opening it a large amount of mucus was found covering the mucosa, which is pale. No food present. A probe one-eighth of an inch in diameter passes through the pyloric orifice easily but leaves no space about it. The pyloric valve is hypertrophied, measuring one-fourth of an inch in thickness, and the circular muscle coat stands out as the cause of the thickening. The thickened area is one inch long. Intestines normal. Section of the pylorus. The glands of the epithelium of the mucosa are normal. The muscular circular coat is very thick; it is thick over a wide area, a distance of one inch from the pyloric opening, where the contrast

between it and the narrow muscular coats of the duodenum is much more marked than is the contrast between it and the slightly less thickened circular muscle of the stomach, beyond the beginning of the pyloric valve. Just at the orifice, the longitudinal muscle is also hypertrophied; but not as markedly as in the circular coat. The mucosa is wider; its rugæ higher, as if the submucosa were looser over the hypertrophied valve than over the rest of the stomach. This difference is very marked, and to it some of the thickness of the valve is due. The vessels are normal and the peritoneal coat also. There is no connective tissue hypertrophied in any coat.

Pathological Anatomy.—Every case examined post-mortem has shown abnormal conditions. An unusual thickness, also length of the pylorus, has always been found. The length is about one inch. The consistency is so firm that it has been described as cartilaginous. Similar conditions have also been found by surgeons operating on these cases. The thickening of the pylorus is most marked at the duodenal end and thins off towards the stomach, so that the pylorus projects into the duodenum in a cone-shaped manner not unlike the portio vaginalis uteri.

The stenosis is not complete, for it is easy to pass a probe through. For practical purposes, it may be regarded as complete in most cases, for the mucous membrane is thrown into folds by the contraction of the fibres of the circular muscle or into one longitudinal fold, which stands out when the pylorus is laid open like the verumontanum in the prostate. "Indeed, the stomach in appearance and feel curiously resembles the dissected out bladder and prostate, the latter being comparable to the pyloric portion. This fold of mucous membrane completes the obstruction of the lumen of the bowel during life" (Cautley).

Microscopic Examination has demonstrated an abnormal thickness of the circular muscular fibres and at times, also, thickening of the longitudinal muscular layer. The entire tumor-like structure consists of muscular tissue as a rule. The products of acute inflammation are scarcely ever found. A

number of authorities have described the presence of other structures: connective-tissue increase between the muscular fibres, thickening of the submucosa, thickening of the mucosa, and in one case an evident secondary small ulcer was found. The serosa was always unchanged. The stomach is often dilated.

Prudden discovered in Meltzer's case a fibrous hypoplasia of the circular muscular fibres. Gran, in 1896, published records of microscopic measurements in cases of stenosis of the pylorus and measurements of the normal pylorus for comparison, which confirmed the gross appearance of hypertrophy. Still, in 1899, reported measurements of eight normal pylori in infants, from one month to twelve months, with which he compared three cases of hypertrophied pylori. He gives the average total thickness of the pyloric walls in healthy infants of six months as 2.5 mm., with a range of one-third more or less. In the case of hypertrophy the total thickness in the three cases was, first, 3.5 mm.; second, 3.7 mm.; third, 5.7 mm. The fact demonstrated by his measurement is, that the chief pathological change in these pylori is an enormous hypoplasia of the circular muscular fibres of the pylorus and adjacent stomach walls.

Pfaundler established an index for the size of the lumen of the pylorus for different ages from birth to twelve months. According to the French scale it runs from nineteen to thirty-two.

Etiology.—Three theories have been advanced in explanation of this condition. Two acknowledge the pathological anatomical lesion as a muscular hypertrophy; one claiming it to be a true malformation; the other to be a secondary hypertrophy due to muscular exercise, occasioned by continuous pyloric spasms, probably existing before birth. The third theory denies the presence of the anatomical lesion, and refers the symptoms to spastic conditions of the pylorus, claiming, that the post-mortem conditions are found in normal stomachs as well.

No case presenting the characteristic symptoms has failed to show the characteristic lesions at autopsy. These anatomical lesions would exclude the symptoms as being due to spasm alone. It is possible that we may find cases of pure pyloric spasm in infants without anatomical lesions, and some of the clinical histories would seem to make this probable. If we feel justified in abandoning Pfaundler's hypothesis of spastic pyloric spasm and assume that there is a true anatomical lesion in most, if not all, of the cases, we must decide, if this is a secondary hypertrophy due to disturbed coördination in the stomach innervation, leading to continued spasm of the pylorus, or if there is an original abnormal development of the muscular structure. The frequent late development of the symptoms after birth would indicate a spastic nature of the condition, but in children presenting symptoms immediately after birth a true stenosis seems indicated. It does not seem reasonable that such a decided hypertrophy could develop in so short a time as the result of spastic contraction.

In assuming the anatomical-obstruction theory it is necessary to explain how many of these children do well for several weeks after birth and then develop the symptoms. It is possible, in these cases, that the hypertrophy of the stomach-wall succeeds in forcing the food through the stenosed pylorus at a time when small quantities of food are taken. When the child takes a larger amount of food the work of expelling it becomes too much for the stomach-wall and the symptoms follow the retention. Swelling of the mucous membrane may lead to increased stenosis at any time. Edmund Cautley believes the condition to be due to a simple redundancy of foetal growth. Nature in her extreme anxiety to provide an effective pyloric sphincter has overexerted herself and has produced too great a quantity of muscular tissue.

Diagnosis is based on the history of progressive wasting, vomiting increasing in frequency and characteristic of pyloric obstruction,—i.e., explosive; constipation, clean tongue, sweet breath, dilatation of the stomach, visible peristalsis, and the

presence of a tumor. It must not be mistaken for simple regurgitation of food so common in infants, or simple gastritis. The absence of bile in the vomitus is also important.

Therapy.—In true stenosis of the pylorus medical treatment has no place, and, if in suspected cases, after ten days or two weeks of the most careful feeding and internal treatment relief is not secured, surgical measures should be adopted, before the infant becomes too debilitated and emaciated.

Meltzer gives the average age at onset as two weeks, and that at death as nine weeks and a half; and states "in view of the remarkable uniformity of the statistics, every case that runs beyond four months cannot be one of almost or quite complete occlusion of the pylorus." Cautley thinks "that the noteworthy fact is, that a fatal issue results before the fourth month of life, in infants not operated upon." Therefore, early diagnosis followed at once by operation, before the infant has had time to lose much weight, or become enfeebled, is especially essential to a successful surgical outcome; even more so, it would appear from the statistics, than the method of operation. Thus of forty cases of gastro-enterostomy with twenty-one recoveries and nineteen deaths, the average age of the successful cases at the time of operation was 6.7 weeks; while the average age at time of operation in the unsuccessful cases was eight weeks. Ibrahims gives nineteen cases with nine recoveries and ten deaths; the average age at time of operation in these was 8.15 weeks.

In the cases in which divulsion was performed, Scudder gives eleven cases with seven recoveries and four deaths; the average age in the successful cases was 6.7 weeks. Ibrahims, fourteen cases, seven recoveries and seven deaths; average age at time of operation, 7.5 weeks.

In cases of pyloroplasty, according to Scudder, of eight cases, four recoveries and four deaths, the average age of successful cases was 6.1 weeks. Ibrahims, nine cases; five recoveries and four deaths; ages not given.

(G. E., GASTRO-ENTEROSTOMY; A. G. E. OR P. G. E., ANTERIOR OR POSTERIOR; P., PYLOROPLASTY; D., DIVULSION.)

Name.	Year.	Age (weeks.)	Opera- tion.	Result.
Stern,	1897	6	G.E.	Died.
Meyer,	1898	6	G.E.	Died.
Meyer,	1898	6	G.E.	Died.
Lobker,	1898	10	P.G.E.	Recovery.
Fritzsche,	1898	6	G.E.	Recovery.
Lobker,	1899	7	P.G.E.	Died.
Abel,	1899	8	A.G.E.	Recovery.
Nicoll,	1899	6	D.	Recovery.
Kehr,	1899	8	G.E.	Recovery.
Kehr,	1899	8	G.E.	Recovery.
Braun,	1900	10	P.	Died.
Schmidt,	1900	8	D.	Recovery.
Stiles,	1900	8	Pylorectomy	Died.
Stiles,	1900	5½	G.E.	Died.
Von Mikulicz,	1900	9	G.E.	Died.
Nicoll,	1900		G.E.	Recovery.
Nicoll,	1900		G.E.	Recovery.
Nicoll,	1900		G.E.	Recovery.
Nicoll,	1900		G.E.	Recovery.
Nicoll,	1900		G.E.	Recovery.
Monnier,	1901	6	A.G.E.	Recovery.
Trautenroth,	1901	5½	A.G.E.	Recovery.
Gruneberg,	1901	5½	D.	Died.
Jordan	1901	7½	G.E.	Died.
Jordon,	1902	9	G.E.	Died.
Gillavry,	1902		P.	Died 5 weeks.
Dent,	1902	8	P.	Recovery.*
Dent,	1902	10	P.	Recovery.
Braun,	1902	6½	G.E.	Died.
Burghard,	1902	8	D.	Recovery.
Burghard,	1902		D.	Recovery.
Stiles,	1902	4	D.	Died.
Stiles,	1902	5	D.	Recovery.
Stiles,	1902	10	D.	Recovery.
Stiles,	1902	9	D.	Died.
Stiles,	1902	5½	D.	Died.
Lendon,	1902		D.	Died.
Granboorn,	1902	3	P.	Died.
Schotten,	1902	6	P.G.E.	Died.

* Died ten weeks after.

Name.	Year.	Age (weeks.)	Opera- tion.	Result.
Grissenn,	1903		D.	Recovery.
Shotten,	1903	5	A.G.E.	Recovery.
Mackay,	1903	20	P.G.E.	Died.
Mackay,	1903	6	D.	Died.
Jakh,	1903	4½	G.E.	Recovery.
Dent,	1903	8	P.	Recovery.
Dent,	1903	6	P.	Recovery.
Dent,	1903	5	P.	Recovery.
Nicoll,			D.	Died.
Nicoll,			D.	Recovery.
Stiles,	1903	4	D.	Died.
Stiles,	1903	10	D. & G.E.	Recovery.
Stiles,	1903	5	D.	Died.
Stiles,	1904	4	P.G.E.	Recovery.
Stiles,	1904	6	P.G.E.	Recovery.
Bull,	1904	4	P.G.E.	Died.
Dent,	1904	7	P.	Recovery.
Campbell,	1904	9	P.	Died.
Pinner,	1904	4	G.E.	Died.
Munro,	1904	7	P.G.E.	Died.
Guthrie,			P.	Recovery.
Bottomley,	1904	8	P.G.E.	Died.
Giles,	1904	7	P.G.E.	Recovery.
Munro,	1904	3	P.G.E.	Recovery.
Elting,	1904	64	A.G.E.	Recovery.
Nicoll,	1904		G.E.	Recovery.
Nicoll,	1904		G.E.	Died.
Nicoll,	1904		G.E.	Died.
Nicoll,	1904		G.E.	Died.
Scudder,	1905	2	P.G.E.	Recovery.
Scudder,	1906	3	P.G.E.	Recovery.
Rodgers,	1906	8	P.G.E.	Recovery.

The total number of cases operated upon is seventy-one. Of these, thirty-eight recovered and thirty-three died, giving 53.53 per cent. recoveries and 46.47 per cent. mortality.

Gastro-enterostomy was performed forty-two times; twenty-four patients recovered and eighteen died, giving 57.14 per cent. recoveries and 42.56 per cent. mortality.

Pyloroplasty was performed in eleven cases, with six

recoveries and five deaths; of the latter, one case survived the operation five weeks and another ten weeks; if these two are added to successful operative cases, it gives us eight recoveries and three deaths. The percentage ratio is as follows: 54.54 per cent. recoveries, 45.46 per cent. mortality, or 72.72 per cent. recoveries and 27.28 per cent. mortality.

Divulsion: Eighteen cases were so operated upon, with nine recoveries and nine deaths. One of the nine cases which recovered had to have a secondary gastro-enterostomy performed three weeks later; therefore, if this can be considered as a failure and added to the cases which died, as it certainly would have, it gives us eight recoveries and ten deaths. The percentage ratio, therefore, is 50 per cent. recoveries and 50 per cent. mortality, or 44.44 per cent. recoveries and 55.55 per cent. mortality.

Pylorectomy, one case; no recoveries and one death; mortality 100 per cent.

The mortality percentages of the four methods of operation, taken from Scudder's, Ibrahims', and my tables are as follows:

	Scudder. per cent.	Ibrahims. per cent.	Fisk. per cent.
Gastro-enterostomy	47.7	52.6	42.5
Divulsion	36.3	50.	50.
			55.5
Pyloroplasty	50.	44.4	45.4
			27.2
Pylorectomy	100.	100.	100.

If the relative percentage for the several operations is to influence the selection of the method of operation to be used, there would appear to be but little choice between gastro-enterostomy, pyloroplasty, and divulsion. But judging from the number of operations relatively in each group, and the opinions of the different writers, gastro-enterostomy appears to be the operation of choice. Of the total number of cases of gastro-enterostomy, the number is about equally divided between the anterior and the posterior operation. This operation

in infants should be done by suturing the parts together, and not by a Murphy's button.

Weill and Péhu consider gastro-enterostomy the operation of choice. Robson and Moynihan believe that gastro-enterostomy is the operation of choice in all such cases.

Scudder, in a recent article, writes that gastro-enterostomy is the operation of choice; Kocher's gastro-duodenostomy subpyloric is physiologically the ideal operation, and Finney's pyloroplasty cannot properly be performed under the physical conditions present because the pyloric tumor is too rigid.

Cautley and Dent, however, whose experience has been large, object to gastro-enterostomy for the following reasons: First, that it necessitates a considerable exposure of the abdominal contents: Second, that the operation must necessarily be more protracted than either pyloroplasty or divulsion of the pylorus: Third, that there is increased risk of protrusion of the intestines; and Fourth, that the incision has to be prolonged further down toward the umbilicus.

Ibrahims says that the shortest operation is the one most indicated, and that pyloroplasty and gastro-enterostomy posterior can hardly be classed as such; and that posterior gastro-enterostomy presents the following disadvantages: the largest incision; the longest time of operation; and the frequent recurrence of intestinal prolapse. Anterior gastro-enterostomy has the same difficulties to a certain extent. Mikulicz successfully operated upon a case by anterior gastro-enterostomy, which died two months later as the result of a diffuse intestinal hæmorrhage due to peptic ulcers in the walls of the duodenum opposite the anastomosis.

Dent contends that results equally good to those of gastro-enterostomy can be obtained by pyloroplasty, and that the operation is, on surgical grounds, to be preferred; also, it can be added, on physiological and anatomical grounds. He considers that the operation of pyloroplasty has been condemned on altogether insufficient grounds.

Monnier says that pyloroplasty is unsafe and often imprac-

ticable on account of the thickness of the pyloric walls. Also Robson and Moynihan write that pyloroplasty on account of the great thickness of the pylorus and its rigidity in its whole circumference is impracticable. "To sum up," writes Dent, "it would appear: First, That the balance of opinion is in favor of gastro-enterostomy, on the ground that recovery follows and that the operation meets the necessity of the case: Second, That pyloroplasty is not so much an unsuitable as an impractical operation." The latter opinion is one that in their cases (Dent's and Cautley's) seems clearly disproved. "Notwithstanding the extreme rigidity and thickness of the hypertrophied pyloric sphincter, no difficulty whatsoever was found in sewing up the wound transversely; indeed, the operation of pyloroplasty would be worthless and impracticable in almost all cases, if rigidity and thickness of the walls constituted an insuperable obstacle to its performance. The operation is really much easier, when the thickness is due to muscular hypertrophy, as in infantile pyloric stenosis, than when the pyloric region is thickened, tough, and fibrous, owing to inflammatory changes.

"In very young children it will be found that the stomach and duodenal walls can be approximated with exceedingly little trouble, and with no tendency whatsoever for the stitches to cut through. There is no need to drag the pylorus up into view. If the distended stomach be gently pressed back into the left flank, the pylorus will almost immediately rise up into the wound without any traction. The peristalsis and distention excited by the exposure and manipulation may be somewhat embarrassing, but the moment that the incision is made into the stomach the distention subsides and the rest of the operation is easy. The incision must divide freely the thickened tissues and extend well into the normal structures on each side. An inch is really rather a short incision and even in a very young child, if it be made considerably longer, there will be no difficulty in approximating the wound transversely. At the upper and lower angles the mucous membrane should be

attached respectively to the stomach and duodenal coats. The introduction and closure of the first suture at the widest part of the wound is likely to approximate the whole of the wound transversely, so that there is little trouble from the escape of the stomach contents. Five or six sutures are ample. The first suture is preferably a Halsted stitch. No difficulty was found in bringing the serous surfaces at the extreme angles of the transverse wound together in a satisfactory manner,—*i.e.*, the part where the thickness and toughness were greatest were almost as easily sewed together as the central normal parts of the wound. Embarrassment from distended intestines, usually the transverse colon, was controlled by simple irrigation with hot normal saline solution. The time of the operation was twenty minutes, and following the operation right decubitus was maintained to effect drainage."

Divulsion of the pylorus was first successfully done by Nicoll. The dilatation is done by means of dilators, urethral bougies, artery lamps, œsophageal dilators, cervical dilators, etc. This operation is crude and not surgically good, because it fails to definitely overcome and remove the cause of the stenosis, recurrence of the stenosis having occurred in a number of cases. Stiles had three recurrences,—one seven days, one eleven days and one three weeks after divulsion. This condition is entirely different from cicatricial stenosis in which when the cicatricial tissue has been thoroughly divulsed the tendency to stenosis is removed, but in hypertrophic stenosis the tendency of the muscular tissue is to again contract and retract also, and, therefore, to reproduce the stenosis. Moreover, decided traumatic injury is usually done, even to laceration of the serosa, which may cause fatal peritonitis.

The operation of pylorotomy is altogether too severe for these cases. It seems, therefore, that the choice of operation is between posterior gastro-enterostomy and pyloroplasty.

It is the opinion of the writer that preference should be given in selected cases to pyloroplasty, as it is physiologically, anatomically, and surgically, the more correct procedure. And

upon the authority of Dent it can be performed as easily and quickly as posterior gastro-enterostomy. Early diagnosis and early operation, before the infant has had an opportunity to lose much in weight, or has become greatly emaciated and enfeebled, so that its reparative power is greatly reduced or lost, is more essential to a successful outcome of surgical treatment than the method of operation, other things being equal. As in most abdominal surgical diseases, of which this must be considered one, delay is generally fatal.